JASSA

Journal of Applied Science in Southern Africa
The Journal of the University of Zimbabwe

Volume 4, Number 1, 1998 **ISSN 1019–7788**

CONTENTS

Editorial

Improvement of *geranium* (*Pelargonium x hortorum*) somatic embryo maturation and conversion by casein hydrolysate and yeast extract
R. M. Madakadze, T. Senaratna and P. K. Saxena

Socio-economic aspects in draught animal-crop linkages: a diagnostic study of Tsholothso, Chinyika and Mutoko smallholder farming areas of Zimbabwe
S. Chawatama, L.R. Ndlovu, K. Dzama, R. Tsimba, J.H. Topps, and J. Mutimba

Residual carrier components in exhausted textile dyebaths
H.M. Kulube

Review on gums of industrial value
M. Muchuweti

Adjusting lactation milk yield of Zimbabwean Holstein dairy cows for the joint effects of age at calving and month of calving
V. Muchenje, F.N. Mhlanga, and S.M. Makuza

Susceptibility of *Pinus oocarpa* to *Armillaria* root disease in Zimbabwe
A.J. Masuka and C.M. Gumbie

Browse preferences of goats in a Savanna rangeland in Zimbabwe
P.H. Mugabe and D. Munthali

Book Reviews
Functions of a Complex Variable
Shell Structures in Civil and Mechanical Engineering

Instructions to Authors

JASSA

Journal of Applied Science in Southern Africa
The Journal of the University of Zimbabwe

Vol. 4, No. 1, 1998
ISSN 1019–7788

CONTENTS

Editorial iii

Improvement of *geranium* (*Pelargonium x hortorum*) somatic embryo maturation and conversion by casein hydrolysate and yeast extract .... R. M. Madakadze, T. Senaratna and P. K. Saxena 1

Socio-economic aspects in draught animal-crop linkages: a diagnostic study of Tsholothso, Chinyika and Mutoko smallholder farming areas of Zimbabwe .... S. Chawatama, L.R. Ndlovu, K. Dzama, R. Tsimba, J.H. Topps, and J. Mutimba 11

Residual carrier components in exhausted textile dyebaths .... H.M. Kulube 19

Review on gums of industrial value .... M. Muchuweti 29

Adjusting lactation milk yield of Zimbabwean Holstein dairy cows for the joint effects of age at calving and month of calving .... V. Muchenje, F.N. Mhlanga, and S.M. Makuza 35

Susceptibility of *Pinus oocarpa* to *Armillaria* root disease in Zimbabwe ... A.J. Masuka and C.M. Gumbie 43

Browse preferences of goats in a Savanna rangeland in Zimbabwe .... P.H. Mugabe and D. Munthali 49

Book Reviews 53

Instructions to Authors 57

Published by University of Zimbabwe Publications
P.O. Box MP203, Mount Pleasant, Harare, Zimbabwe

Typeset by University of Zimbabwe Publications
Printed by Mazongororo Paper Converters

Review on gums of industrial value

M. Muchuweti

Department of Biochemistry, University of Zimbabwe, P.O. Box MP 167, Mount Pleasant, Harare, Zimbabwe.

There is an increasing trend towards the use of available plant resources for food and technological applications. One class of ingredients often exploited for their texturizing capabilities are the plant polysaccharides called the hydrocolloids or gums. These compounds are long chain polymers which dissolve in water to give a thickening or viscosity-building effect. Some of these plant polysaccharides have found applications in the food, pharmaceutical, textile, mining and other industries. The United States Food and Drug Administration regulates gums, classifying these compounds as food additives. Though required at usage levels of less than two percent to achieve the desired properties in food systems, gums have become a big business. In 1991 the market of gums reached 126 metric tons at a worth of $748.7 million. There is an increased awareness of the nutritional importance of polysaccharides. The demand for water-soluble polysaccharide gums including the seaweed extracts, seed gums, plant exudates and cellulose derivatives, has slowly increased over the past few years along with population growth and the advent of easy to prepare foods. Effective use of gums requires that their chemical and physical properties be understood as much as possible. This article gives a review of some of the polysaccharide gums of industrial value.

Keywords: Plant polysaccharides, gums, application, chemical and physical properties.

Introduction

Gums and mucilages are long chain polymers which dissolve or disperse in water to give a thickening or viscosity–building effect. They are also commonly known as hydrocolloids (Sharma, 1981). The structure of the gums and mucilages is very complicated as they consist of branched chains, built up from a variety of units including uronic acids, pentoses and methylpentoses (Doby, 1965; Musgrave *et al.*, 1979,1983). The properties of a particular gum sample depend on the source, climate and harvest conditions. There are various sources of gums which include seaweeds, seeds, exudates, gums obtained by microbial biosynthesis and gums obtained from the chemical modification of the natural polysaccharides (Aspinall, 1970; Bhat and Tharanathan, 1987).

The use of gums and mucilages dates back thousands of years. The wrappings of Egyptian mummies were held together with an Arabic mucilage. Agar and other seaweeds have a long history of use in food and medicine.

Today, gums have many and varied uses in the food and other industries. They are used as binding agents in sausages, emulsifiers in salad dressings and stabilizers in flavour emulsions among many other uses, in fact, the chemical components of gums are present in almost every natural food and are largely responsible for their structure and textural properties. The natural plant gums can be classified into four major categories according to raw material source or origin. They are seed gums, seaweed extracts, plant exudates and cellulose derivatives.

Seed Gums

Seed gums include locust bean gum and gar gum and are isolated from plants that are specifically grown for that purpose. Locust bean gum also called carob, is made up of mannose and galactose in the ratio of 4:1 (Neukom, 1989). The gum is a neutral polysaccharide which is present in the endosperm of seeds obtained from evergreen tree *Ceratonia silqua* which is indigenous to

Mediterranean countries. Locust bean gum is insoluble in cold water and must be heated to dissolve it. In ancient times the Egyptians used the gum for its adhesive properties in mummification. Locust bean gum functions as an extremely versatile thickener, suspending, stabilizer, and water–binding agent. The stabilising and water binding characteristics of locust bean gum determine its excellent functionality in ice cream, cheese and other dairy products, dough, pie fillings, and dry and frozen sauces. Locust bean gum and its derivatives are excellent film formers and are widely used as print thickeners in roller and screen printing as well as in finishing agents. The gum is still used as a wet end additive in paper making where it results in an improved sheet with greater strength. The availability of this gum varies. Current production is estimated to be 15 000 tons *per annum* at a price of Z$3.97 to Z$4.63 depending on the grade.

Guar gum is obtained from the ground endosperm of an annual plant which is native to the arid climates of India and Pakistan. Forming the backbone of the gum is a linear chain of mannose residues with galactose units attached as side chains in the ratio of one galactose unit for every mannose units. Guar gum hydrates fully in cold water because it is more highly substituted than locust bean gum. The high thickening efficiency and good compatibility combined with the wide availability and low cost have resulted in Guar gum being the most extensively used gum in both food and industrial applications. It is used as a stabilizer in ice cream and frozen deserts, to which it imparts body, texture, and heat shock resistance. The biggest industrial user of Guar gum is the paper industry. It is added to the pulp where it contributes to hydrogen bonding between cellulose fibers, facilitating wet end processing and resulting in improved sheet formation and products with improved dry and wet strength. The same hydrogen–bonding properties and the consequent interaction with the hydrated surfaces of clay or ore particles have led to the widespread use of the gum in the mining industry. For various operations it is used as a flocculant, a flotation agent, a foam stabilizer, a filtration aid and a water treatment agent in the disposal of waste water. In the textile industry it is used as a print–paste thickener. The estimated production of Guar gum is at 10 million tons *per annum* at a price of Z$2.69 to Z$3.08/kg (Carson, 1980; Figuiredo, 1990; Carlson *et al.*, 1962).

Exudate Gums

Exudate gums include gum arabic, gum ghatti, gum karaya and gum tragacanth which are dried resins that are expelled from wounded parts of trees to protect tissues (Kordofani and Ingrouille, 1991). Gum arabic is the dried sap which is exuded from various species of Acacia trees when wounded. There are about 115 species in Africa (Ross, 1979; Pettigrew and Watson, 1975; and 1973). The exudate apparently serves to prevent desiccation of the tissue beneath. Once hardened, the sap is collected by hand by peasants and sold at the market after sorting, cleaning, grading and processing steps that transform the gum into a form which is usable by industry (Rebbertse, 1974; Anderson, 1969 and 1974).

Chemically, gum arabic is a neutral polysaccharide containing calcium, magnesium and potassium ions. The gum consists of rhamnose, arabinopyranose, arabinofuranose, glucuronic acid and O–methylglucuronic acid (Dziezak, 1991). Also present in the gum is a small amount of protein. Gum arabic dissolves readily in hot or cold water and is the least viscous and most soluble of all known hydrocolloids. The main uses of gum arabic are based on its properties of emulsification, protective action, adhesiveness, thickening, binding and stabilisation. Gum arabic is used as an adhesive in glazes and toppings of bakery products, as foam stabilizer in beer, as a crystalline inhibitor in sugar, syrups and candies and as a stabilizer in many flavour emulsions.

Gum arabic also has applications in pharmaceticals and cosmetics as a stabilizing and emulsifying aid, as a suspending agent, as a demulcent in cough syrups, as an adhesive and a binder in tablets, and as an emulsion stabilizer in protective creams and lotions. The principal nonfood uses are in lithography and in the manufacture of inks and adhesives. Normal *per annum* production is at 40 000 metric tons and a price of US$1.58/kg to US$3.00/kg

Gum ghatti, also called an Indian gum, is produced by *Anogeissus latiforia* which is a tree native to India. The gum is a water soluble, complex polysaccharide consisting of arabinose, mannose, xylose and glucuronic acid. The gum is made up of a soluble fraction and an insoluble one. The gum is non–gelling but can be dispersed in hot or cold water tc give a colloidal solution that develops due to the soluble fraction. In the food and pharmaceutical industries gum ghatti is used in many of the applications described for gum arabic. Current prices are US$1.23/kg.

Gum karaya is the dried exudate of the *Sterculia* tree which grows in central and northern India. It is a partially acetylated complex polysaccharide which consists of a major chain comprising galacturonic acid, rhamnose, galactose with some side chains containing glucuronic acid (Dziezak, 1991; Anderson, 1969). Gum karaya is the least soluble of all exudate gums. It does not dissolve in water but absorbs water and swells, producing a viscous colloidal sol. Although boiling the dispersions of gum karaya increases the solubility of the gum, it also reduces the viscosity. Gum karaya has a limited but important application in the paper industry, where it is used in the production of lightweight papers from long cellulose fibers. Prices range from US$2.65 to US$3.08/kg depending on grade.

Gum tragacanth is the exudate produced by certain species of the *Astragalus* bush, a leguminous perennial that is native to Asia Minor and to the semi–desert and mountainous regions of Iran, Syria and Turkey. Gum tragacanth is composed of a mixture of polysaccharides which includes tragacanthic acid, a water soluble component which confers water–swelling properties to the gum and arabinogalactan and gives the gum its solubility. Gum tragacanth produces the most viscous solutions of all plant hydrocolloids.The stability of the gum to heat and acid and its effectiveness in emulsification add to its potential utility in industries (Dziezak, 1991). The gum has been widely used as a thickener and stabilizer and gives good shelf stability to acidic products such as pourable salad dressings, mayonnaise, relishes, pickles and fruit pie fillings. The gum is widely used for the preparation of pharmaceutical emulsions, jellies, as a thickener emulsifier and lubricant and also as in the cosmetic industry in face and hair lotions. The price of gum karaya is currently US$29.77 to US$33.79/kg.

Algal Gums

Seaweeds exist for the greatest part of their lives as attached organisms, monitoring the environment of passing currents and waves. Seaweeds differ from higher plants in that they do not possess true roots stems or leaves. From the industrial point of view it is the phaeophyceae and the rhodophyceae that are most important as sources of carbohydrate polymers, partly because the algae occur in sufficient quantities to possess commercial value (Chapman, 1970 and 1962; Lobban, 1985). Seaweed gum extracts include alginates, agar and carrageenan. The seaweed polysaccharides are used in a variety of foods and industrial products as well as pharmaceutical industry (Evans, 1986; Cheney and Mumford, 1985).

Alginates are present in the cell walls of a number of brown plants including *Ascophyllum nodosum, Laminaria longcrusris, Lminaria digitata and Pelveta canaliculata.* Alginates are the various salts of alginic acid and comprise of a variety of products that are made up of mannuronic acid and glucuronic acid arranged in regions composed solely of one unit or the other. The differences in structure in the various types of alginates are responsible for the differences in their properties in the plants in which they are found. Alginates are used in the manufacture of paper to control the flow properties of coating. In the manufacture of textiles alginates are used to prevent migration of dyestuffs in pad dyeing operations. Alginates are compatible with most fiber reactive dyes.

The emulsification properties of alginates are valuable in the emulsification of oils and suspension of solids necessary for the manufacture of polishes. Extensive investigations of the toxicological properties of alginates have shown that they are safe to use in foods. Alginates have also found wide applications in medical biotechnology for the immobilisation of cells and enzymes, an application which can be applied in the manufacture of non–irritant wound dressing which could be easily and painlessly removed without damaging the scar tissue (Dziezak, 1991).

Even within the same species, a great variation exists in alginates from different parts of the same plant (Haug, *et al*., 1974). Both the ratio of mannuronic acid and glucuronic acid residues and the structure of the polymer determine the solution properties of the alginate. Mixtures of alginic acid and various alginates can be designated for many different gelling and viscosity controlling functions in a wide range of food, biochemical and industrial products (Moss, 1977; Yamamoto, 1992; Blumreisinger, 1983).

Agar is a major constituent of the cell walls of certain red algae, especially members of the *Gelidiaceae* and *Gracilariaceae* families. The term agar is now generally applied to those algal galactans which have the disaccharide agarobiose as the repeating unit. Agar is not soluble in cold water but dissolves completely in hot water. The major uses of agar are in foods and microbiological media for culturing. Agar is stable to most organisms, but there are a few organisms that either produce agarolytic enzymes or metabolize agar. Agar is not digestible but because of its colloidal and gelling properties it is used in such foods as pie fillings, icings, toppings and meringues (Cardinal and Percival, 1977).

Carrageenans are sulphated polymers which consist of galactose and anhydrogalactose units and are obtained from red seaweed, the best known of which is called *Chondrus crispus*. Because of the economic importance of carrageenans much work has been done on its biochemistry. *Chondrus crispus* has been cultured extensively for the production of carrageenan (Neish and Shacklock, 1971; Harvey and McLachlan, 1973). Three main fractions of carrageenan preparations which differ primarily in the content and distribution of the sulphate ester groups have been identified. These are iota, kappa and lambda carrageenan. The structure and molecular weight of the fractions determine their functional properties. Most of the uses of carrageenan are in the food industry. A small amount is used in cosmetics and pharmaceuticals. Carrageenans have been used for entrapment of bacterial cells (*Brevebacterium flavum)* containing an enzyme fumarase for the production of L–malate, a substitute of citrate in food technology. Carrageenans have been used for immobilisation of bacteria or yeasts (*Saccharomyces cerevisiae*) for the production of ethanol (Lecacheux and Brigand, 1988; McCandles and Craigie, 1979; Mizuno 1992).

Microbial Gums

Xanthan gum is a high molecular weight polysaccharide which is produced by culturing the microorganism *Xathomonas campestris* on a carbohydrate medium. The bacterium was originally isolated from *rutabaga* plant. The gum has a cellulosic backbone with trisaccharide branches attached to every other unit in the main chain. High viscosities are achieved when the gum is used in combination with Guar gum. Xanthan gum is completely soluble in cold or hot was and produces high viscosities at low concentrations. The toxicological and safety properties of xanthan gum have been extensively investigated. Short term and long term feeding tests on rats and dogs have shown that it is not acutely toxic, has no growth inhibiting activity, has nonsignificant effects on survival, organ weights, or haematological values, and does not cause tumours. On this basis the FDA issued a food additive order in 1969 that allowed the use of xanthan gum in food products. Xanthan gum is used in of French dressing, cottage cheese creaming emulsions, stabilisation of toothpaste, denture powders and colostomy adhesives, canned gravy–type pet foods, liquid cattle feed supplements and calf milk replacers. One of the important uses of xanthan gum is in the recovery of crude oil. The flow characteristics of xanthan gum coupled with its stability to salts and extremes of pH, give it a technical advantage over most polymers in drilling needs (Tako, 1992).

Gellan gum, approved for use by the FDA only in 1990, is manufactured by a fermentation process. It is produced by culturing *Pseudomonas elodea* on a carbohydrate medium. The gum has a linear backbone comprising of glucose, glucuronic acid and rhamnose. Gellan gum forms strong gels at concentrations as low as 0.05 percent. Gel texture can be modified by blending with other gums such as Guar gum or carrageenan (Dziezak, 1991).

Cellulose Derivatives

Cellulose derivatives are a family of products that are made by modifying cellulose. Cellulose is a long chain polymer found in most land plants and it consists of glucose subunits. Normally insoluble, cellulose only becomes soluble in water when the polymer is chemically modified. Each cellobiose unit which makes up the backbone of the cellulose consists of two anhydroglucose units, which in turn have three hydroxyl groups each. Alkaline treatment, conducted under controlled conditions, converts cellulose into an ether by substituting the hydrogen on some of the hydroxyl groups with a carboxyl group. The length of the cellulose ethers that are obtained as well as the nature and the number of the ether groups influence the solubility, gelling and thickening properties of the derivative. Examples of chemically modified celluloses are carboxymethylcellulose, methylcellulose and hydropropylmethylcellulose. The major markets for carboxymethylcellulose are detergents (30 percent); foods and pharmaceuticals (27 percent); textiles (20 percent); drilling muds; paper sizing, and coating (3 percent) and miscellaneous markets, including adhesives, ceramics, latex paints and welding rod coating (5 percent). The U.S. productions has been estimated to be at 150 million metric tons *per annum* at a cost of US$3.60/kg . Methylcellulose has been used in a variety of food products including salad dressings, pie fillings, and baked goods. Non–food applications include adhesives, agricultural chemicals, ceramics, wall joint and tile cements, leather finishing, paint, cosmetics and pharmaceuticals. Methylcellulose ethers are manufactured under the Methocel trademark by the Dow Chemical Company. The price ranges from US$3.53 to US$4.64/kg (Aspinall, 1970).

There is a lot of research being done to isolate, purify and characterise gums of plant origin with potential uses in industries in the department of Biochemistry at the University of Zimbabwe. Preliminary studies have shown that mucilaginous polysaccharides isolated from the local plant *Diceorocryum zanguebarium (ruredzo)* have a potential in the fabrication of food products and other applications in which the gums described above have been used (Benhura and Marume, 1993; Benhura and Mavhudzi, 1996).

The leaves of ru*redzo* produce copious amounts of slimy mucilage. It is this property that has probably been responsible for the use of *ruredzo* by tribal people in Southern Africa in the treatment of measles, cleansing and facilitation of births. The leaves are also used in the preparation of *derere* which is a dish that is enjoyed partly for it's slimy consistency. The plant which grows as a sprawling creeper in much of Southern and Central Africa produces fruit which bears two upward pointing spines from which the plant derives it's latin name (Tredgold, 1986; Wild, 1972; Woolfe, *et al.*, 1977). Although the structure of the mucilage has not been determined studies have shown that the mucilage contains galactose, xylose, arabinose and mannose in the ratio of 21:19:12:1 and has emulsifying properties.

Work is also being done in the Department of Biochemistry at the University of Zimbabwe by Benhura's research group to isolate and characterize gums and mucilages from the fruits of plants such as *Azanza garkeana* and *Cordia abbyssinica*. Characterisation of the polysaccharide gums from the fruits will facilitate evaluation of methods to most effectively exploit the gums in industries. *Azanza* fruit, which is the source of the mucilage material, already exists on the market and is sold in more or less large amounts in various urban centres. It is anticipated that if suitable applications of gums from local plants are identified then reliable sources of the gums would be readily available rather than importing. In Zimbabwe a company by the name Bush Broake Allen uses exudate gums exuded by various species of Acacia tree. Once the sap is hardened it is collected by hand by natives and is sold at the market, eventually making its way through the sorting, cleaning, grading and processing steps that transform it into a form which is usable in industry.

REFERENCES

ANDERSON, D.M.W., BELL, P. AND MILLAR, J.R.A. 1974 Composition of gum exudates from *Ancardium occidentale*. *Phytochemistry* **47:** 12–26.

ANDERSON, D.M.W. AND BELL, P. 1969 The composition and properties of the gum exudate from *Terminalia sericea* and *Terminalia superba*. *Phytochemistry* **13:** 1871–1874.

ASPINALL, G.O. 1982 In: Polysaccharides.Ed., G.O. Aspinall). vol.1. Academic Press, New York, 19.

BENHURA, M.A.N. AND MARUME, M. 1993 The mucilaginous polysaccharide material isolated from *ruredzo* (*Dicerocryuam zanguebarium*). *Food Chemistry* **46:** 7–11.

BENHURA, M.A.N. AND MAVHUDZI, I. 1996 Use of crosslinked mucilage prepared from *Ruredzo* (*Dicerocryuam zanguebarium*) in the purification of polygalacturonase extracted from tomato. *Food Chemistry* **56:** 433–437.

BHAT, U.R. AND THARANATHAN, R.N. 1987 Functional properties of okra (*Hibiscus esculentus*) mucilage. *Starch/Starke* **39:** 165–167.

BLUMREISINGER, M., MEINDL, D. AND LOOS, E. 1972 Cell wall composition of chloroccal algae. *Phytochemistry* **22 (7):** 1603–1604.

CARDINAL, G.E. AND PERCIVAL, E. 1977 The carbohydrates of the green seaweed *Urospora wormskiodii* and *Codiolum pusillum*. *Carbohydrate Research* **57**: 223–234.

CARLSON, W.A. 1980 Carob as a food – a historical review. *Lebensm–Wis.u–Technology* **13**: 51–52.

CARLSON, W.A., ZIEGENFUSS, E.M. AND OVERTON, J.D. 1962 Compatibility and manipulation of Guar gum. *Food Technology* **16(10):** 50–54.

DOBY, G. 1965 Plant Biochemistry. Interscience Publishers, London, New York. 221–243.

DZIEZAK, J.D. 1991 A focus on gums. *Food Technology* **45(3):** 116–132.

EVANS, L.V. 1986 Seaweed bioproducts. *Science in Progress* Oxford **70:** 287–303.

FUGUEIREDO, A.A. 1990 Mesquite: history, composition and food uses. *Food Technology* **44 (7):** 118,128.

HAUG, A., LARSEN, B AND SMIDROD, O. 1974 Uronic acid sequence in alginate from different sources. *Carbohydrate Research* **32**: 217–225.

KORDOFANI, M. AND INGROUILLE, M. 1991 Patterns of morphological variation in Acacia species. *Botanical Journal of the Lennaean Society* **105:** 239–265.

LECACHEUX, D. AND BRIGAND, G. 1988 Preparative fractionation of natural polysaccharides by size exclusion chromatography. *Carbohydrate Polymers* **8:** 119–130.

MCCANDLES, E.L. AND CRAIGIE, J.S. 1979 Sulphated polysaccharides in red and brown algae. *Annual Review Plant Physiology* **30:** 41–53.

MIZUNO, T., ANDO, M., SUGIE, R., ITO, H., SUMIYA, T. AND MATSUUTA, A. 1992 Antitumor activity of some polysaccharides from edible mushroom, *Ningyotake*, the fruiting body and the cultured mycelium of *Polyporous confluens*. *Bioscience, Biotechnology and Bichemistry* **56(1)**: 34–41.

MOSS, J.R. 1978 Essential considerations for establishing seaweed extraction factories. In: Marine plants biomass of Pacific Northwest Coast. Ed. R.W. Krauss. Oregon State University Press, Corvallis 201–304.

NEISH, A.C., SHACKLOCK, P.F., FOX, C.H. AND SIMPSON, F.J. 1977 The cultivation of *Chondrus crispus*. Factors affecting growth under greenhouse conditions. *Canadian Journal of Botany* **55:** 2263–2271.

TREDGOLD, M.H. 1986 Food plants of Zimbabwe. Mambo Press, Gweru, Zimbabwe. 7.

WILD, H.A.1972 A Rhodesian dictionary of African and English plant names Government Printer, Salisbury. 147.

WOOLFE, M.L., CHAPLIN, M.F. AND OTCHERE, G. 1977 Studies on the mucilages extracted from okra fruits. (*Hibiscus esculentus*) and baobab leaves (*Adansonia digitata*). *Journal of Food Science and Agriculture.*